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Carla J. Dove
Smithsonian Institution, Feather Identification Lab, Washington, DC, dovec@si.edu

Nor Faridah Dahlan
Smithsonian Institution, Feather Identification Lab, Washington, DC

Marcy Heacker
Smithsonian Institution, Feather Identification Lab, Washington, DC

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Carla J. Dove, Smithsonian Institution, Feather Identification Lab, National Museum of Natural History, E-600, MRC 116, P.O. Box 37012, Washington, DC 20013-7012, USA *dovec@si.edu*
Nor Faridah Dahlan, Smithsonian Institution, Feather Identification Lab, National Museum of Natural History, E-601, MRC 116, P.O. Box 37012, Washington, DC 20013-7012, USA
Marcy Heacker, Smithsonian Institution, Feather Identification Lab, National Museum of Natural History, E-601, MRC 116, P.O. Box 37012, Washington, DC 20013-7012, USA

Abstract: On March 4, 2008, a Cessna Citation 1 (Model 500) crashed in a wooded area near Wiley Post Airport, Oklahoma, killing all 5 people on board. This paper describes the detailed forensic methods and expertise used by the Smithsonian Institution's Feather Identification Lab to identify the bird that caused this bird-strike incident. We used standard methods of whole-feather analysis, microscopic examination, and DNA barcoding in this case to identify American white pelican (*Pelecanus erythrorhynchos*) as the bird species involved in this fatal crash. We also report the importance of proper field investigation and evidence collection for accurate results, particularly for this case, and generally for all bird-strike identifications.

Key Words: aircraft collision, bird strike, crash, DNA, feather, human–wildlife conflicts, identification, *Pelecanus erythrorhynchos*, white pelican, Wiley Post Airport

Aircraft collisions with birds (bird strikes) are a safety and economic concern for the aviation industry (Dolbeer and Wright 2008, 2009; Dale 2009). The Smithsonian Institution has been providing bird identifications from fragmentary feather evidence of bird strikes since the early 1960s. We identify birds to various taxonomic levels using morphological feather characters of size, shape, color, and texture; microscopic characters of node shape, barbule length, distribution, and pigmentation patterns (Chandler 1916; Brom 1991; Dove 1997, 2000; Rajaram 2002; Dove and Agreda 2007); and, more recently, for bird-strike analysis by using DNA barcoding (Dove et al. 2008). For bird-strike cases, these techniques can be used independently or in combination, if the evidence from the bird-strike mishap is minute or insufficient for any single technique. Identifications also are corroborated with circumstantial evidence from the bird-strike event (e.g., date, geographic location, eye witness reports) to help validate the final species identifications.

On March 4, 2008, at approximately 1515 hours Central Time, a Cessna Citation 1 (Model 500) crashed in a wooded area about 7 km from Wiley Post Airport, Oklahoma, killing all 5 people on board. An eyewitness reported seeing a flock of birds in the area about the time of the crash (Professional Pilot News 2008). Two days after the crash, the Feather Identification Lab at the Smithsonian Institution (National Museum of Natural History) was contacted by the National Transportation Safety Board (NTSB) to assist with the analysis of evidence recovered from this accident. The Cessna Citation was bound for Mankato, Minnesota, and crashed shortly after takeoff. The cockpit voice recorder was not operating during the flight, adding to the difficulty of this investigation.

This paper describes the techniques used by the Feather Identification Lab for all bird-strike identification cases, and it specifically details the methods applied to the accident investigation at Wiley Post. The cumulative information obtained from identification of bird species from bird-strike mishaps is vital to proper implementation of management plans to reduce the risk of bird strikes, improve engine and aircraft design, assist with accident investigations; and it significantly contributes to our knowledge of the damage that birds and wildlife can cause to aviation safety.

Methods

Reporting

Bird strikes are reported online according to procedures established by the U.S. Air Force (USAF) and the Federal Aviation Administration (FAA). Bird evidence (bird remains) typically is collected by field personnel (e.g., pilots, maintenance crew, airport biologists) according to procedures established by each agency (FAA 2009). A copy of the wildlife strike report, including the unique case number and all details pertaining to the mishap, is attached to the packaged bird remains and submitted to us for identification. For international cases, the proper permits and certificates for international export requirements also are included with the bird remains.

In the Wiley Post Airport case, the staff wildlife biologist for the U.S. Department of Agriculture (USDA)/Animal and Plant Health Inspections Service (APHIS) program in Oklahoma became aware of the reported circumstances surrounding the crash and immediately offered to assist the FAA and National Transportation Safety Board (NTSB) with the evidence-collecting for this event. The NTSB, took the lead in this investigation and was the designated point of contact. All information, including dissemination of the bird identification, was the responsibility of the NTSB and all reports, media contact, and public inquiries went through the NTSB until the investigation was closed. NTSB cases are open until the cause of the accident is determined.

Sampling

Bird remains, such as whole feathers and large biological samples, usually are collected simply by picking or scraping the material off the aircraft. If whole birds or nearly complete carcasses are encountered, feathers are plucked (not cut) from the breast, wings, tail, and back of the bird. The feathers are then placed in marked zip-lock plastic bags. If the sample is too dry to be removed by scraping, 70% alcohol is sprayed on the area to loosen the materials before sampling or wiping. The alcohol helps prevent the growth of mold on the sample and is especially important to the success of DNA extraction. In cases where only blood or tissue is present, DNA samples can be collected using Whatman® FTA cards (Whatman International Ltd., Kent, U.K.).

Traditional morphological identifications of fragmented feathers are best done in a museum research collection where the remains of whole feathers or feather fragments can be properly cleaned (Laybourne and Dove 1994) and examined microscopically or sampled for DNA analysis. Feather identification often relies on examination of both the pennaceous and plumulaceous (downy) feather barbs (Figure 1).

In the Wiley Post Airport case, the USDA wildlife biologist who inspected the crash site on March 6 (2 days after the event) recognized a splatter pattern on the tail section of the aircraft (Figure 2) and immediately sampled the area using Whatman ® FTA cards and associated sponge applicators. Initial field samples were obtained from the top right horizontal stabilizer,

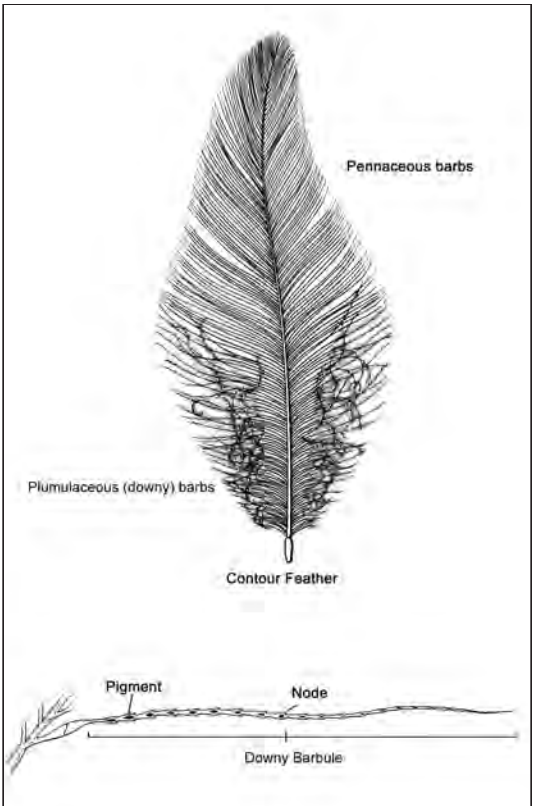

Figure 1. Topography of a contour feather showing the pennaceous and plumulaceous (downy) parts of a feather and some typical microscopic characters (e.g., pigment, node) of the downy barbules.

bottom right horizontal stabilizer, right side of the vertical stabilizer, and the interior right cowling. Twenty-four microscopic slides were made according to methods described in Dove (2000), and nearly 100 DNA samples were submitted from the total field samples. In subsequent weeks, items from the cockpit, windshield, and various areas of the engine were transferred to the Smithsonian's Feather Identification Lab where each package and part was examined for bird evidence. A final sampling event occurred on July 1, 2008, at the NTSB office in Washington, D.C., to search for bird material on a piece of the right engine's inlet duct.

For DNA analysis, we took 2 hole-punches from each Whatman® FTA card and processed them according to the manufacturer's instructions; we processed additional minute tissue samples from the sponge applicators according to DNA tissue extraction procedures using Qiagen DNeasy® Blood and Tissue Kit (Qiagen Inc., Valencia, Calif.). We compared the DNA sequences to the Barcode of Life Database (BoLD) as described in Dove et al. (2008).

Figure 2. USDA wildlife biologists (Phil Robinson, left, and Karen Duncan, right) collecting evidence at the scene of the airplane crash near Wiley Post Airport, Oklahoma. The tail section (background) of the aircraft contained bird remains (DNA and feather barbs) that were vital to the species identification in this case. *(Photo courtesy Phil Robinson)*

Results

Feather identification

We found a single portion of a small white feather and 7 feather barbs (3 downy barbs and 4 pennaceous barbs) associated with evidence in the Wiley Post Airport accident. The white, partial feather was retrieved by an NTSB investigator from material wrapped around a riveted bolt that was part of the disintegrated material from the burned right engine's inlet duct. The USDA wildlife biologists in the field at the time of the accident collected the minute feather barbs attached to the Whatman® FTA cards or included with the sponge applicators that were used to swab the aircraft. The 3 downy feather barbs associated with the sponge applicators contained microscopic characters sufficient for possible identification. These samples were collected from the aircraft's top right horizontal stabilizer, bottom right horizontal stabilizer, and right side of the vertical stabilizer. The microscopic characters of the 3 samples of downy barbs were similar to each other and included unpigmented barbs and short barbules with long prongs on the distal portion of the barbule (Figure 3). These microscopic characters are typical of several birds that could occur in Oklahoma during the month of this accident (April) and includes the avian Orders: Gaviiformes (loons),

Figure 3. Photomicrograph of a downy feather sample collected from the tail section of the Cessna Citation that crashed near Wiley Post Airport, Oklahoma. The diagnostic microscopic characters of the downy barbs in this sample include short barbules with long, distal prongs.

Podicipediformes (grebes), and Pelecaniformes (pelicans, cormorants, etc.). From these Orders of birds, possible suspects included common loons (*Gavia immer*), horned grebes (*Podiceps auritus*), eared grebes (*P. nigricollis*), pied-billed grebes (*Podilymbus podiceps*), western grebes (*Aechmophorus occidentalis*), double-crested cormorants (*Phalacrocorax auritus*), and American white pelicans (*Pelecanus erythrorhynchos*).

Because the feather evidence was minute, and the microscopic characters were similar to multiple species, we relied on the DNA analysis for initial identification guidance. DNA results usually can be obtained for bird-strike identifications in about 6 days (Dove et al. 2008), but in this priority case we obtained results in 4 days. On March 11, 2008, we obtained >620 base-pair portions of mitochondrial DNA cytochrome oxidase 1 (CO1) from 3 of the initial Whatman® FTA card or tissue samples. All three of the sequences matched the BoLD database at >99% to the library sequences for American white pelican. Samples testing positive for American white pelican were taken from the aircraft's top right horizontal stabilizer, the bottom right horizontal stabilizer, and the right side of vertical stabilizer. We did not find feather or DNA evidence from the interior engine cowling.

The white, partial feather and the pennaceous feather barbs from the Wiley Post Airport event were not useful for microscopic identification. The white, partial feather confirmed that the unknown bird had white feathers, which supported 1 eyewitness account of the incident (Fros 2008).

After the DNA samples provided a confident species match, we reexamined the microscopic structures of the downy barbules found in the Wiley Post Airport accident case and confirmed that the feather characters were consistent with those of American white pelican (Figure 4). We eliminated the common loon and various species of grebes because those species typically have stippled pigment in the internodes of the downy barbules. We eliminated double-crested cormorants because the distal downy prongs are typically shorter and fewer in number than those of the Cessna sample. That species also does not have white feathers in the plumage at that time of the year, which was inconsistent with the white, partial pennaceous feather in our sample.

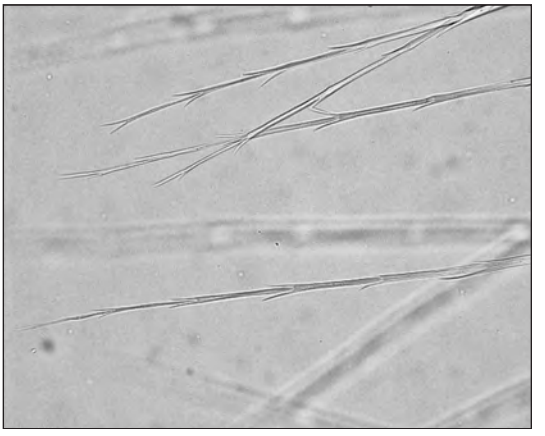

Figure 4. Photomicrograph of downy barbs of American white pelican (*Pelecanus erythrorhynchos*) showing the microscopic similarity to the unknown sample (Figure 3) from the Wiley Post accident.

We did not find any feather material or bird DNA in any of the samples from the cockpit materials, left engine, or windshield. We recovered additional synthetic fibers, human hair, and miscellaneous fibers from some of the samples. We were unable to determine if >1 bird was involved in this accident or if the white partial feather from the right engine material was the same bird that struck the tail section. All of the feather samples, microscope slides, and other items of evidence were returned to the NTSB investigator in June 2008.

Discussion

Although the identification process is similar in all bird-strike mishaps, the number of samples analyzed, comprehensive examination, time involved, and interagency communication was much more intensive and detailed for this investigation because >100 samples were analyzed in this case. Proper knowledge and recognition of various microscopic fibers (i.e., synthetic, plant, hair, etc.) were vital to the rapid processing of the material in this case. From the hundreds of microscope slides and DNA samples that we examined from this accident, we found only 7 feather fragments and 3 viable DNA samples from one of the largest birds in North America. The average weight of the American white pelican is 7.5 kg (Sibley 2000). The American white pelican is common during the spring in Oklahoma (Newell 2006). On March 14, 2008, the USDA staff biologist who assisted with the on-site investigation noted 17 white pelicans at Lake Overholser, <2 km from the crash site. The American white pelican has been recognized as one of the 36 species in North America with a body mass that exceeds the maximum bird mass standards established by the FAA that must be tested for airframes, windshields, and engines (Dolbeer and Eschenfelder 2003). The U.S. Air Force Bird–Animal Aircraft Strike Hazard (BASH) wildlife-strike database includes 20 mishaps involving American white pelicans since 1985, totaling >$257 million in damages (E. LeBoeuf, USAF-BASH chief, personal communication). The FAA Wildlife Strike database includes 5 American white pelican strikes since 2004 with two of those occurring in April 2008 in Colorado and Minnesota (S. Wright, FAA Wildlife Strike Database manager, personal communication). Further, this species is experiencing population increases of 4.3% (mean annual rate) in North America (Sauer et al. 2008) and is predicted to present wildlife hazards to general aviation at smaller airports in the coming decades, as the interest in very light jets increases (Dolbeer et al. 2008).

The U.S. Air Force requires bird-strike reporting and species identification, and the FAA recommends it on a voluntary basis (Cleary and Dolbeer 2005). Currently, the USAF obtains bird identifications in >50% of the total bird strikes annually (E. LeBoeuf, U.S. Air Force BASH chief, personal communication), whereas civil aviation estimates only a 24% bird identification rate (Dolbeer and Wright 2008). Management programs to reduce wildlife risks to aircraft depend on accurate species identification as the first step in prevention. The techniques and methods described here demonstrate the ability to identify bird species from minute evidence and will hopefully encourage aviation personnel to participate in BASH programs that will ultimately improve safety by defining our knowledge of the exact species of birds that are hazardous to aircraft.

The detailed analysis in the Wiley Post Airport mishap case and the care taken to collect evidence in the field and after the accident were vital to the successful identification of the bird species in this accident. Aviation accident investigation teams need to develop protocols to ensure that when a bird is suspected in a crash or damaging mishap, bird remains are searched for and properly collected by biologists familiar with bird-strike evidence recovery.

Advances in DNA technology for bird-strike identification (Dove et al. 2008) and the years of experience in microscopic examination of feather fragments allowed a 100% confidence level of success in bird identification for this case. We obtained six of the feather samples and all three of the DNA samples from the initial evidence collected from the tail of the aircraft, underscoring the importance of recognizing the signs of a bird strike in the field and of collecting the evidence immediately after the mishap. Proper field collecting and the experience of the USDA biologist allowed NTSB investigators and Smithsonian Institution's Feather Lab personnel to be instrumental in the successful bird identification in this case

Acknowledgments

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Literature cited

Brom, T. G. 1991. The diagnostic and phylogenetic significance of feather structures. Instituut voort Taxomomische Zoologische, Amsterdam, Netherlands.

Chandler, A. C. 1916. A study of feathers, with reference to their taxonomic significance. University of California Publications in Zoology 13:243–446.

Cleary, E. C., and R. A. Dolbeer. 2005. Wildlife hazard management at airports: a manual for airport personnel. Second edition. Federal Aviation Administration, Office of Airport Safety and Standards, Washington, D.C., USA.

Dale, L. A. 2009. Personal and corporate liability in the aftermath of bird strikes: a costly consideration. Human–Wildlife Conflicts 3:216–225.

Dolbeer, R. A., M. J. Begier, and S. E. Wright. 2008. Animal ambush: the challenge of managing wildlife hazards at general aviation airports. Proceedings of the corporate aviation safety seminar, Palm Harbor, Florida. Flight Safety Foundation, Alexandria, Virginia, USA.

Dolbeer, R. A., and P. Eschenfelder. 2003. Amplified bird-strike risks related to population increases of large birds in North America. International Bird Strike Committee, Warsaw, Poland.

Dolbeer, R. A., and S. E. Wright. 2008. Wildlife-strikes to civil aircraft in the United States, 1990–2007. U. S. Department of Transportation Serial Report 14, Federal Aviation Administration, Washington, D.C., USA.

Dolbeer, R. A., and S. E. Wright. 2009. Safety management systems: how useful will the FAA National Wildlife Strike Database be? Human–Wildlife Conflicts 3:167–178.

Dove, C. J. 1997. Quantification of microscopic feather characters used in the identification of North American plovers. Condor 99:47–57.

Dove, C. J. 2000. A descriptive and phylogenetic analysis of plumulaceous feather characters in Charadriiformes. Ornithological Monographs 51, American Ornithologists' Union, McLean, Virginia, USA.

Dove, C. J., and A. Agreda. 2007. Differences in plumulaceous feather characters of dabbling and diving ducks. Condor 109:192–199.

Dove, C. J., N. C. Rotzel, M. Heacker, and L. A. Weigt. 2008. Using DNA barcodes to identify species involved in bird strikes. Journal of Wildlife Management 72:1231–1236.

Dunning, J. B., Jr., editor. 2008. CRC handbook of avian body masses. Second edition. CRC, New York, New York, USA.

FAA. 2009. Airport wildlife hazard mitigation home page, <http://wildlifemitigation.tc.faa.gov/public_html/index.htm>, Federal Aviation Administration. Accessed February 5, 2009.

Fros, A. 2008. Bird expert may offer only clue in city plane crash mystery. The Oklahoman, March 13, 2008. Oklahoma City, Oklahoma, USA.

Knopf, F. L., and R. M. Evans. 2004. American white pelican (*Pelecanus erythrorhynchos*) *in* A. Poole, editor. Birds of North America online <http://bna.birds.cornell.edu/bna/species/057 doi:10.3173/bna.57>, Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed February 6, 2009.

Laybourne, R. C., and C. J. Dove. 1994. Preparation of bird-strike remains for identification. Pages 531–534 *in* Proceedings of the Bird-strike Committee Meeting, August 29–September 2, 1994, Vienna, Austria.

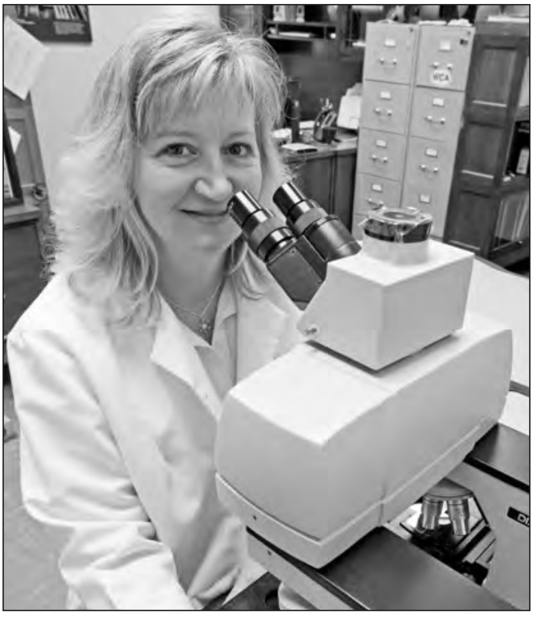
Newell, J. G. 1984. Central Oklahoma bird checklist. Revised 2006. Oklahoma City Audubon Society Bird Records Committee, Oklahoma City, Oklahoma, USA.

Professional Pilot News. 2008. Five perish in Cessna Citation crash in Oklahoma, March 10, <http://propilotnews.com/2008/03 five-perish-in-cessna-citation-crash-in.html>. Accessed February 6, 2009.

Rajaram, A. 2002. Barbule structure of bird feathers. Journal of Bombay Natural History Society 99:250–257.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. North American breeding bird survey, results and analysis, 1966–2007. Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Sibley, D. A. 2000. Sibley guide to birds. National Audubon Society, Chanticleer Inc., New York, New York, USA.



Carla J. Dove is the program director of the Feather Identification Lab, Smithsonian Institution, Washington, D.C. She specializes in microscopic research of feather ultrastructure to identify birds by examination of downy barbs. This work has been applied to anthropology, ecological studies of prey remains, and the identification of birds involved in bird strikes. She holds a Ph.D. degree from George Mason University.

Marcy Heacker is a research assistant at the Feather Identification Lab, Smithsonian Institution, Washington, D.C., where she conducts identification of bird species through analysis of whole feathers or feather fragments in comparison with museum specimens. She holds an M.S. degree from George Mason University. (*Author photos by Chip Clark*)

Nor Faridah Dahlan is a genetics specialist at the Feather Identification Lab, Smithsonian Institution, Washington, D.C. She uses DNA analysis to identify blood and tissue samples received from bird strikes. She holds a B.S.degree from the University of Washington–Seattle.